APPENDIX D

Human Health Effects from Transportation

TA-18

APPENDIX D
HUMAN HEALTH EFFECTS FROM TRANSPORTATION

D.1 INTRODUCTION

Transportation of any commodity involves a risk to both transportation crew members and members of the public. This risk results directly from transportation-related accidents and indirectly from the increased levels of pollution from vehicle emissions, regardless of the cargo. The transportation of certain materials, such as hazardous or radioactive waste, can pose an additional risk due to the unique nature of the material itself. To permit a complete appraisal of the environmental impacts of the proposed action and alternatives, the human health risks associated with the transportation of Technical Area (TA)-18 nuclear materials are assessed.

This appendix provides an overview of the approach used to assess the human health risks that may result from transportation. The topics in this appendix include the scope of the assessment, packaging and determination of potential transportation routes, analytical methods used for the risk assessment (e.g., computer models), and important assessment assumptions. It also presents the results of the assessment. In addition, to aid in the understanding and interpretation of the results, specific areas of uncertainty are described with an emphasis on how the uncertainties may affect comparisons of the alternatives.

The risk assessment results are presented in this appendix in terms of "per-shipment" risk factors, as well as for the total risks for a given alternative. Per-shipment risk factors provide an estimate of the risk from a single shipment. The total risks for a given alternative are found by multiplying the expected number of shipments by the appropriate per-shipment risk factors.

D.2 SCOPE OF ASSESSMENT

The scope of the transportation human health risk assessment, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, and transportation modes considered, is described below. Additional details of the assessment are provided in the remaining sections of the appendix.

Proposed Action and Alternatives

The transportation risk assessment conducted for this environmental impact statement (EIS) estimates the human health risks associated with the transportation of radioactive and special nuclear material currently stored at TA-18. Consistent with the scope of the transportation human health risks, this evaluation focuses on using onsite and offsite public highways. Impacts associated with onsite transportation of material in support of the Los Alamos National Laboratory (LANL) New Facility Alternative are addressed qualitatively. Impacts associated with offsite transportation of materials to Sandia National Laboratories/New Mexico (SNL/NM), Nevada Test Site (NTS) and Argonne National Laboratory-West (ANL-W) are quantitatively evaluated.

Transportation-Related Activities

The transportation risk assessment is limited to estimating the human health risks related to transportation for each alternative. The risks to workers or to the public during loading, unloading, and handling prior to or after shipment are included in the transportation assessment. The transportation risk assessment does not address possible impacts from increased transportation levels on local traffic flow, noise levels, or infrastructure.

Radiological Impacts

For each alternative, radiological risks (i.e., those risks that result from the radioactive nature of the materials) are assessed for both incident-free (i.e., normal) and accident transportation conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people.

All radiological impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The radiation dose calculated is the total effective dose equivalent (see 10 CFR 20), which is the sum of the effective dose equivalent from external radiation exposure and the 50-year committed effective dose equivalent from internal radiation exposure. Radiation doses are presented in units of roentgen equivalent man (rem) for individuals and person-rem for collective populations. The impacts are further expressed as health risks in terms of latent cancer fatalities and cancer incidence in exposed populations using the dose-to-risk conversion factors established by the National Council on Radiation Protection and Measurement (NCRP 1993).

Nonradiological Impacts

In addition to the radiological risks posed by transportation activities, vehicle-related risks are also assessed for nonradiological causes (i.e., causes related to the transport vehicles and not the radioactive cargo) for the same transportation routes. The nonradiological transportation risks, which would be incurred for similar shipments of any commodity, are assessed for both incident-free and accident conditions. The nonradiological risks during incident-free transportation conditions would be caused by potential exposure to increased vehicle exhaust emissions. The nonradiological accident risk refers to the potential occurrence of transportation accidents that directly result in fatalities unrelated to the shipment of cargo. Nonradiological risks are presented in terms of estimated fatalities.

Transportation Modes

All shipments are assumed to take place by truck transportation modes. Rail transportation is not practical at TA-18 or any of the potential receiving sites, and the U.S. Department of Energy (DOE) has considerably more experience safeguarding special nuclear material on the highways.

Receptors

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck crew members involved in the actual transportation and the site workers involved in repackaging, loading and unloading the materials. The general public includes all persons who could be exposed to a shipment while it is moving or stopped during transit. The affected population includes individuals living within 800 meters (0.5 miles) of each side of the road. Potential risks are estimated for the affected populations and for the hypothetical maximally exposed individual. For incident-free operation, the maximally exposed individual would be an individual stuck in traffic next to the shipment for 30 minutes. For accident conditions, the maximally exposed individual would be an individual located 33 meters (108 feet) directly downwind from the accident. The risk to the affected population is a measure of the radiological risk posed to society as a whole by the alternative being considered. As such, the impact to the affected population is used as the primary means of comparing various alternatives.

D.3 PACKAGING AND REPRESENTATIVE SHIPMENT CONFIGURATIONS

Regulations that govern the transportation of radioactive materials are designed to protect the public from the potential loss or dispersal of radioactive materials, as well as from routine radiation doses during transit. The primary regulatory approach to promote safety is the specification of standards for the packaging of radioactive materials. Because packaging represents the primary barrier between the radioactive material being transported and radiation exposure to the public and the environment, packaging requirements are an important consideration for transportation risk assessment. Regulatory packaging requirements applicable to the TA-18 radioactive and special nuclear material (SNM) are discussed below. The representative packaging and shipment configurations assumed for this EIS also are described below.

D.3.1 Packaging Overview

Although several Federal and state organizations are involved in the regulation of radioactive material transportation, primary regulatory responsibility resides with the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission (NRC). All transportation activities must take place in accordance with the applicable regulations of these agencies as specified in 49 CFR 172 and 173 and 10 CFR 71.

Transportation packaging for small quantities of radioactive materials must be designed, constructed, and maintained to contain and shield their contents during normal transport conditions. For large quantities and for more highly radioactive material, such as high-level radioactive waste or spent nuclear fuel, they must contain and shield their contents in the event of severe accident conditions. The type of packaging used is determined by the total radioactive hazard presented by the material within the packaging. Four basic types of packaging are used: Excepted, Industrial, Type A, and Type B. Another packaging option, “Strong, Tight,” is still available for some domestic shipments.

Excepted packages are limited to transporting materials with extremely low-levels of radioactivity. Industrial packages are used to transport materials that, because of their low concentration of radioactive materials, present a limited hazard to the public and the environment. Type A packages are designed to protect and retain their contents under normal transport conditions and must maintain sufficient shielding to limit radiation exposure to handling personnel. These packages are used to transport radioactive materials with higher concentrations or amounts of radioactivity than Excepted, or Industrial packages. Strong, Tight packages are used in the United States for shipment of certain materials with low-levels of radioactivity, such as natural uranium and rubble from the decommissioning of nuclear reactors. Type AF packages (the “F” stands for fissile material) are designed to carry material with relatively low radioactivity levels with additional requirements to prevent a fission chain reaction under severe transportation conditions. Type B packages are used to transport material with the highest radioactivity levels, are designed to protect and retain their contents under transportation accident conditions, and are described in more detail in the following sections.

D.3.2 Regulations Applicable to Type B Casks

Regulations for the transport of radioactive materials in the United States are issued by the U.S. Department of Transportation and are codified in 49 CFR 173. The regulation authority for radioactive materials transport is jointly shared by the Department of Transportation and the NRC. As outlined in a 1979 Memorandum of Understanding with the NRC, the U.S. Department of Transportation specifically regulates the carriers of radioactive materials and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. The U.S. Department of Transportation also regulates the labeling, classification, and marking of all radioactive material packages. The U.S. Department of Transportation also has a specification for one Type B package, the 6M, that could be used to transport TA-18 materials. NRC sets the standards for packages containing Type B quantities of radioactive material, fissile materials and spent nuclear fuel.

DOE policy requires compliance with applicable Federal regulations regarding domestic shipments of radioactive materials. Accordingly, DOE has adopted the requirements of 10 CFR 71, *Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions*, and 49 CFR 173, *Shippers--General Requirements for Shipping and Packaging*. DOE Headquarters can issue a certificate of compliance for a package to be used only by DOE and its contractors. Packages certified by NRC, certified by DOE or specified by the U.S. Department of Transportation could be used to transport TA-18 material.

For certification, transportation casks must be shown by analysis and/or testing to withstand a series of hypothetical accident conditions. These conditions have been internationally accepted as simulating damage to transportation casks that could occur in most reasonably foreseeable accidents. The impact, fire, and water-immersion tests are considered in sequence to determine their cumulative effects on one package. These accident conditions are described in **Figure D–1**.

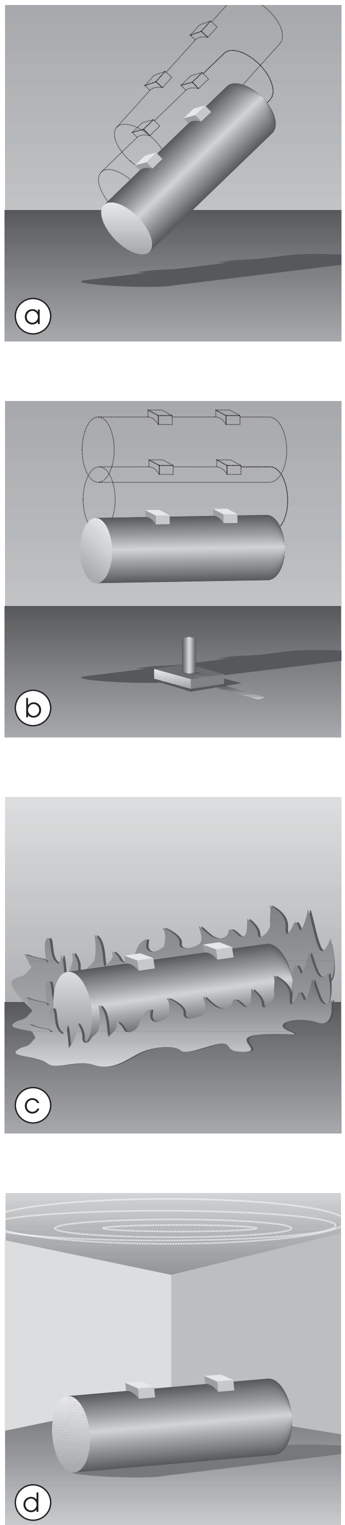
Under the Federal certification program, a Type B packaging design must be supported by a Safety Analysis Report for Packaging (SARP), which demonstrates that the design meets Federal packaging standards. The SARP must include a description of the proposed packaging in sufficient detail to identify the packaging accurately and provide the basis for evaluating its design. The SARP must provide the evaluation of the structural design, materials' properties, containment boundary, shielding capabilities, and criticality control, and present the operating procedures, acceptance testing, maintenance program, and the quality assurance program to be used for design and fabrication. Upon completion of a satisfactory review of the SARP to verify compliance with the regulations, a Certificate of Compliance is issued. For risk assessment purposes, it is important to note that all packaging of a given type is designed to meet the same performance criteria. Therefore, two different Type B designs would be expected to perform similarly during incident-free and accident transportation conditions.

D.3.3 External Radiation Limits

External radiation from a package must be below specified limits that minimize the exposure of handling personnel and the general public. For these types of shipments, the external radiation dose rate during normal transportation conditions must be maintained below the following limits of 49 CFR 173:

- 10 millirem per hour at any point 2 meters (6.6 feet) from the vertical planes projected by the outer lateral surfaces of the transport vehicle (referred to as the regulatory limit throughout this document), and

- 2 millirem per hour in any normally occupied position in the transport vehicle



Standards for Type B Casks

For certification to the U.S. Nuclear Regulatory Commission standards, a cask must be shown by test or analysis to withstand a series of accident conditions without releasing its contents. These conditions have been internationally accepted as simulating damage to spent nuclear fuel casks that could occur in most severe credible accidents. The impact, fire, and water-immersion tests are considered in sequence to determine their cumulative effects on one package. An undamaged containment system is subjected to a deep water-immersion test. The details of the tests are as follows:

Impact

Free Drop (a) – The cask drops 9 meters (30 feet) onto a flat, horizontal, unyielding surface so that it strikes at its weakest point.

Puncture (b) – The cask drops 1 meter (40 inches) onto a 15.2-centimeter (6-inch) diameter steel bar at least 20.3 centimeters (8 inches) long; the bar strikes the cask at its most vulnerable spot.

Fire (c)

After the impact tests, the cask is totally engulfed in an 802 °C (1,475 °F) thermal environment for 30 minutes.

Water Immersion (d)

The cask is completely submerged under at least 1 meter (40 inches) of water for 8 hours. Additionally, undamaged containment systems (casks) are required to withstand more rigorous immersion tests.

Figure D–1 Standards for Transportation Casks

Additional restrictions apply to package surface contamination levels, but these restrictions are not important for the transportation radiological risk assessment. Current contamination standards assure that workers and public receive doses much lower than those associated with radiation emitted from the packages.

D.4 GROUND TRANSPORTATION ROUTE SELECTION PROCESS

According to DOE guidelines, radioactive material shipments must comply with both the NRC and the U.S. Department of Transportation regulatory requirements. NRC regulations cover the packaging and transport of radioactive materials, whereas DOT specifically regulates the carriers and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. The highway routing of nuclear material is systematically determined according to the U.S. Department of Transportation regulation 49 CFR 397 for commercial shipments. Specific routes cannot be publicly identified in advance for DOE's Transportation Safeguards Division's shipments because they are classified to protect national security interests.

The U.S. Department of Transportation routing regulations require that shipments of highway route-controlled quantities of radioactive material be transported over a preferred highway network, including interstate highways, with preference toward interstate system bypasses and beltways around cities and state-designated preferred routes. A state or tribe may designate a preferred route to replace or supplement the interstate highway system in accordance with the U.S. Department of Transportation guidelines (49 CFR Section 397.103).

Carriers of highway route-controlled quantities are required to use the preferred network unless they are moving from their origin to the nearest interstate highway or from the interstate highway to their destination, they are making necessary repair or rest stops, or emergency conditions render the interstate highway unsafe or impassable. The primary criterion for selecting the preferred route for a shipment is travel time. Preferred routing takes into consideration accident rate, transit time, population density, activities, time of day, and day of the week.

Representative routes that may be used for the shipments were selected for risk assessment purposes using the HIGHWAY code. They do not necessarily represent the actual routes that would be used to transport nuclear materials. The selection of the actual route would be responsive to environmental and other conditions that would be in effect or could be predicted at the time of shipment. Such conditions could include adverse weather conditions, road conditions, bridge closures, and local traffic problems. For security reasons, details about a route would not be publicized before the shipment.

The HIGHWAY computer code (Johnson et al. 1993) is used for selecting highway routes in the United States. The HIGHWAY database is a computerized road atlas that currently describes over 386,000 kilometers (240,000 miles) of roads. The Interstate System and all U.S. (US-designated) highways are completely described in the database. In addition, most of the principal state highways and many local and community roads are also identified. The code is updated periodically to reflect current road conditions and has been benchmarked against reported mileages and observations of commercial truck firms. Features in the HIGHWAY code allow the user to select routes that conform to U.S. Department of Transportation regulations. Additionally, the HIGHWAY code contains data on the population densities along the routes. The distances and populations from the HIGHWAY code are part of the information used for the transportation impact analysis in this *TA-18 Relocation EIS*.

D.5 SAFEGUARDED TRANSPORTATION

DOE anticipates that any transportation of SNM would be required to be made through use of the Transportation Safeguards System and shipped using Safe, Secure Trailers/Safeguards Transports (SST/SGTs). Transportation safeguards are required for (1) nuclear explosives; (2) components moved in a single shipment that could comprise a complete nuclear explosive; (3) any form of uranium-235 enriched 20 percent or greater in quantities of 5 kilograms (11 pounds) or more, or uranium-233 or plutonium in quantities of 2 kilograms (4.4 pounds) or more; (4) classified forms of plutonium and uranium-235 regardless of quantity as requested by Heads of Field Elements; (5) DOE-owned plutonium in any quantity to be transported by air; or (6) any form of plutonium-238 in excess of 5 grams (0.18 ounce) (DOE Order Supplemental Directive AL 5610.14). The SST/SGT is a fundamental component of the Transportation Safeguards System.

The SST/SGT is a specially designed component of an 18-wheel tractor-trailer vehicle. While 49 CFR Section 173.7(b) exempts SST/SGT shipments from U.S. Department of Transportation regulations, DOE operates and maintains these vehicles in a way that exceeds U.S. Department of Transportation requirements. Although details of vehicle enhancements and some operational aspects are classified, key characteristics of the SST/SGT system include the following:

- Enhanced structural characteristics and a highly-reliable tie-down system to protect cargo from impact.
- Heightened thermal resistance to protect the cargo in case of fire (newer SST/SGT models).
- Established operational and emergency plans and procedures governing the shipment of nuclear materials.
- Various deterrents to prevent unauthorized removal of cargo.
- An armored tractor component that provides courier protection against attack and contains advanced communications equipment.
- Specially designed escort vehicles containing advanced communications and additional couriers.
- 24-hour-a-day real-time communications to monitor the location and status of all SST/SGT shipments via DOE's Security Communication system.
- Couriers, who are armed Federal officers, receive rigorous specialized training and are closely monitored through DOE's Personnel Assurance Program.
- Significantly more stringent maintenance standards than those for commercial transport equipment.
- Conduct of periodic appraisals of the Transportation Safeguards System operations by the DOE National Nuclear Security Administration to ensure compliance with DOE orders and management directives, and continuous improvement in transportation and emergency management programs.

The Transportation Safeguards System is operated by the DOE Transportation Safeguards Division of the Albuquerque Operations Office for the DOE Headquarters National Nuclear Security Administration. Based on operational experience between fiscal year 1984 and fiscal year 1998, the mean probability of an accident requiring the tow-away of the SST/SGT was 0.058 accidents per million kilometers (0.096 accidents per million miles) (Claus and Shyr 1999). By contrast, the rate for commercial trucking in 1989 was about 0.3 accidents per million kilometers (0.5 accidents per million miles) (Saricks and Tompkins 1999). Accident rates for commercial trucking and SST/SGTs were used in the human health effects analysis. Since its establishment in 1975, the Transportation Safeguards Division has accumulated more than 151 million kilometers (94 million miles) of over-the-road experience transporting DOE-owned cargo with no accidents resulting in a fatality or release of radioactive material.

Loading and unloading of SST/SGTs at DOE sites is routinely done in accordance with site facility and Transportation Safeguards Division procedures. The DOE SST/SGT operations team directs and approves loading and securing of packages within SST/SGT vehicles and is solely responsible for closing and securing SST/SGT vehicles and cargo areas prior to transport.

Task interactions between Transportation Safeguards Division operations teams, the SST/SGT operations center, the shipping and receiving sites, and security personnel involved in loading, securing, and dispatching SST/SGT shipments are conducted in accordance with the requirements of DOE Orders 461.1, 5632.1C, and 474.1 and SST/SGT operations procedures. In dispatching shipments, DOE's SST operations team and operations center also coordinate with the security operations center at a DOE site. Estimated time of arrival, shipment, and material accountability information is transmitted to designated persons at the receiving site in accordance with prearranged protocols. DOE anticipates the time necessary to prepare, load, secure, and dispatch SST/SGTs to be on the order of less than 1 day (per convoy).

SGT and SST have similar dimensions. The general dimensions for SST are given below (Ludwig et al. 1997):

Gross vehicle weight rating	36,288 kilograms (80,000 pounds)
Maximum payload	6,169 kilograms (13,600 pounds)
Trailer overall length	18.3 meters (60 feet)
Trailer overall width	259 centimeters (102 inches)
Trailer overall height	4 meters (13 feet)
Trailer rear door width	179.1 to 215.9 centimeters (70.5 to 85 inches)
Trailer rear door height	229 centimeters (90 inches)
Trailer floor height above roadway	144 centimeters (56.5 inches)
Tractor trailer minimum turning radius	11.4 meters (37.5 feet)

D.6 TRANSPORTATION IMPACT ANALYSIS METHODOLOGY

The transportation risk assessment is based on the alternatives described in Chapter 3 of this EIS. After the EIS alternatives were identified, and the requirements of the shipping campaign were understood, data was collected on the material characteristics and accident parameters. Section D.7 describes these parameters. **Figure D–2** summarizes the transportation risk assessment methodology.

Transportation impacts calculated in this EIS are presented in two parts: impacts from incident-free or routine transportation, and impacts from transportation accidents. Impacts from incident-free transportation and transportation accidents were further divided into nonradiological and radiological impacts. Nonradiological impacts from incident-free transportation would be impacts from vehicular emissions and from transportation accidents would be traffic fatalities. Radiological impacts from incident-free transportation include impacts to members of the public and crew from radiation emanating from materials within the package. Only under worst case accident conditions, which are of low probability of occurrence, could a transportation package of the type used to transport radioactive and SNM be damaged to the point that radioactivity could be released to the environment.

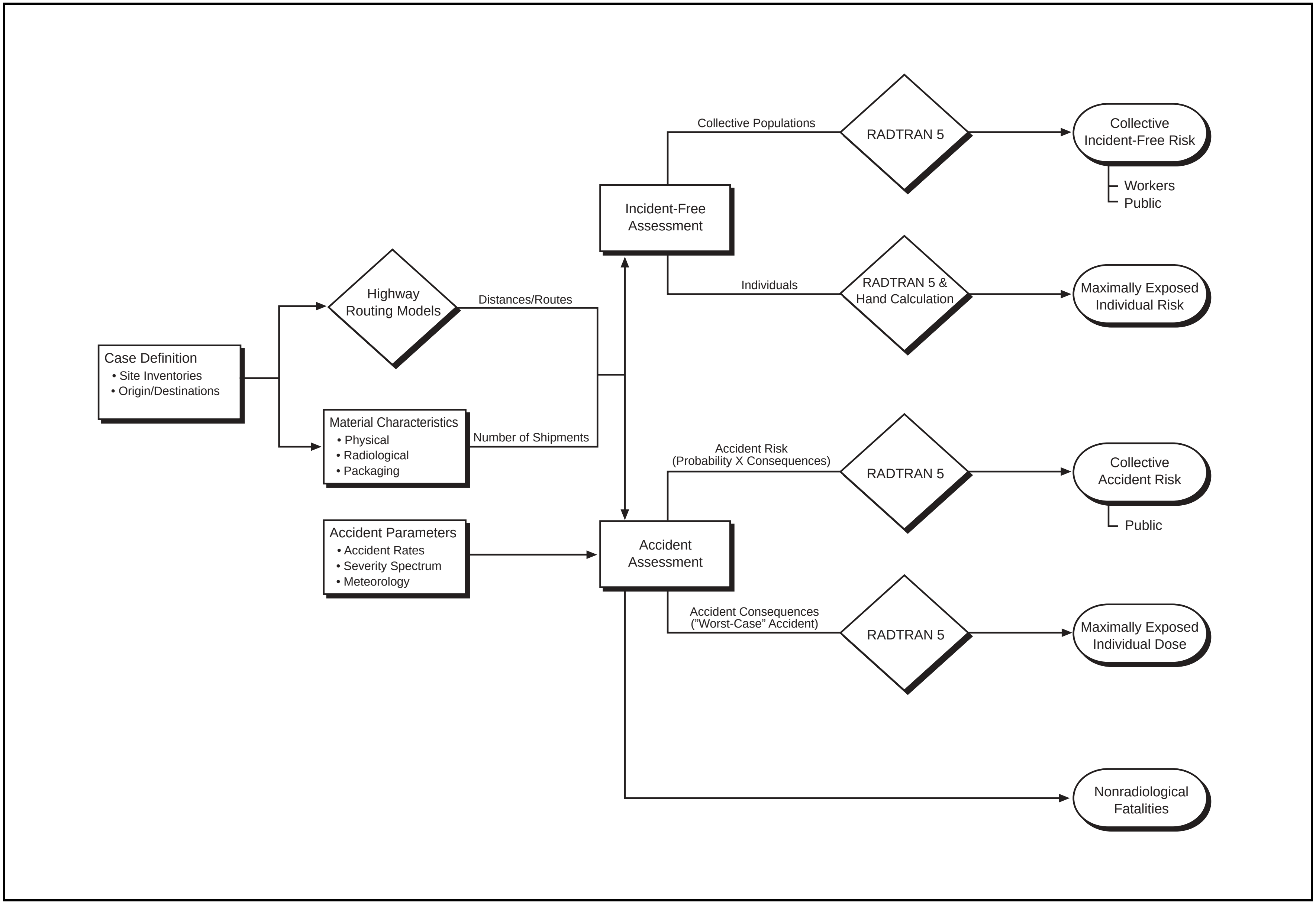


Figure D–2 Overland Transportation Risk Assessment

The impact of transportation accidents is expressed in terms of probabilistic risk, which is the probability of an accident multiplied by the consequences of that accident and summed over all reasonably conceivable accident conditions. Hypothetical transportation accident conditions ranging from low-speed "fender-bender" collisions to high-speed collisions with or without fires were analyzed. The frequencies of accidents and consequences were evaluated using a method developed by the NRC and originally published in NUREG-0170 (NRC 1977). The risk of radiological accidents is expressed in terms of additional latent cancer fatalities and risk of nonradiological accidents is expressed in terms of additional immediate fatalities. Incident-free risks are also expressed in terms of additional latent cancer fatalities.

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck crew members involved in the actual transportation, and workers involved in the packaging, loading, unloading and unpacking of TA-18 material. The general public includes all persons who could be exposed to a shipment while it is moving or stopped during transit.

The first step in the ground transportation analysis is to determine the distances and populations along the routes. The HIGHWAY (Johnson et al. 1993) computer code was used to choose representative routes and the associated distance and population. This information, along with the properties of the material being shipped and route-specific accident frequencies, was entered into the RADTRAN 5 computer code (Neuhauser and Kanipe 2000), which calculated incident and accident risks on a per-shipment basis. The per-shipment risks are multiplied by the number of shipments to determine the risk for each alternative. The doses to TA-18 workers are estimated in a separate analysis.

The RADTRAN 5 computer code (Neuhauser and Kanipe 2000) is used for incident-free and accident risk assessments to estimate the impacts on population. RADTRAN 5 was developed by Sandia National Laboratories to calculate population risks associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge. RADTRAN 5 was used to calculate the doses to the maximally exposed individuals.

The RADTRAN 5 population risk calculations include both the consequences and probabilities of potential exposure events. The RADTRAN 5 code consequence analyses include cloud shine, ground shine, inhalation, and resuspension exposures. The collective population risk is a measure of the total radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing the various alternatives.

D.7 TRANSPORTATION ANALYSIS, PARAMETERS, AND ASSUMPTIONS

D.7.1 Material Inventory and Shipping Campaigns

The materials that would be transported under each alternative include approximately 2.4 metric tons (2.6 tons) of SNM and 10 metric tons (11 tons) of depleted natural uranium and thorium. The SNM would consist of uranium in all forms and enrichments and plutonium (mostly metals, double-encapsulated or clad) with a wide variety of contents including plutonium-240, uranium-233, neptunium-237, and other isotopic sources. The materials would be in various chemical (metals, oxides, alloys, etc.) and geometric (sphere, shell, cylinders, rings, plates, and others) forms specific to the experiments in support of the TA-18 operations. Since the specifics of isotopic composition and the shape of the materials to be transported are classified, for the purposes of analysis in this EIS, the SNM inventory has been converted to an equivalent amount of plutonium-239. The conversion is on a constant consequence-basis, so the consequences calculated in the accident analyses are exactly the same as they would be if the actual material inventory were used. The equivalent inventory of plutonium-239 to be transported in support of the TA-18 relocation is approximately 1,000 kilograms (2,205 pounds).

DOE has performed a survey of materials to be transported and has identified a preliminary estimate of the packaging and transportation needs. DOE has identified that the materials would be packaged in either a Type AF, in a Type B, in a National Nuclear Security Administration weapon component, or in a U.S. Department of Transportation specification packaging. The packages include SAFKEG, DT-22, DT-23, Model FL, ES-2100, and 6M. Some of the proposed packages would require additional analysis and modifications to Certificates of Compliance. Before shipping any materials, DOE would document compliance with the Federal regulations in effect at the time of the shipment. Most of the material currently stored at TA-18 can be accommodated within current and proposed DOE-owned packages or readily available commercial packages. However, since shipments would not be carried out for several years, some existing packages may be retired and substitute packages identified.

DOE has not yet completed a package-by-package, shipment-by-shipment plan for relocating TA-18 materials. This will not be performed until after an alternative is selected and the Record of Decision is published. Since the isotopic composition and shape of some of the materials are classified, part of this plan would have to be classified. DOE's preliminary analysis of the shipping requirements indicates a need for 87 SST/SGT shipments (Lanthrum 2001) of assorted radioactive and SNM (enriched uranium, plutonium, and other fissile isotopes) and 5 truck shipments for machines, depleted and natural uranium, and thorium, for a total of 92 shipments.

D.7.2 General Description of Packages Selected for Transportation of Nuclear Materials

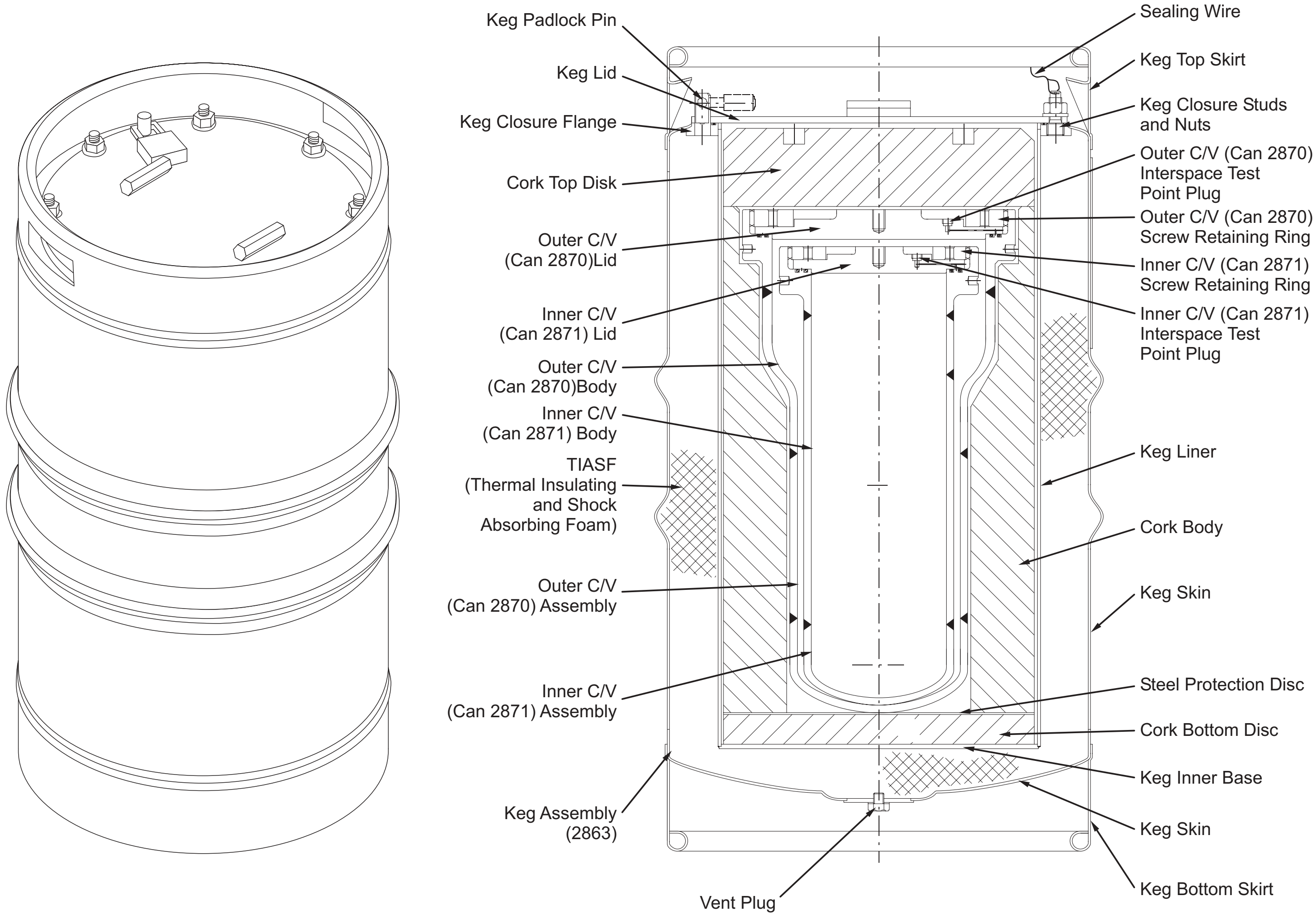
Most of the material currently stored at TA-18 can be accommodated within current and proposed DOE-owned packages or readily available commercial packages. DOE could choose to design new or use existing similar packaging. A select list of packages is described in detail to show the reader typical features of these packages. These packages have been used for the purpose of estimating input parameters, such as number of shipments and mass of contents, for the purpose of the impact analysis. Any new packages of similar designs could be used. Similar packaging would be designed to the same level of safety and would be expected to have similar features.

D.7.2.1 SAFKEG Packages

The SAFKEG 2863B packaging (see **Figure D–3**) consists of a CROFT keg model number 2863 (Keg 2863) which is 760 millimeters (30 inches) long and 425 millimeters (16.7 inches) diameter, and carries a double containment configuration using resealable containment vessels, model numbers 2870 and 2871 (Can 2870 and Can 2871). This packaging is to be used as a general purpose container for the shipment of solid or powder fissile or other actinide material. The contents have been limited such that the packaging does not require exclusive use provisions. The permitted internal heating of the contents is 30 watts. The allowable modes of transport are: road, rail, sea, and air (except that air shipment of plutonium is not allowed within the United States in this packaging). The package shall be externally labeled by the user in accordance with 49 CFR 172 subpart E. The SAFKEG 2863B package meets all applicable requirements of 10 CFR 71.

A SARP has been prepared to support a Certificate of Compliance for the SAFKEG 2863B shipping package (DOE 1999). Approval for use is requested in accordance with 49 CFR 173.7(d). The SARP addresses applicable NRC, DOE and the U.S. Department of Transportation rules and regulations regarding packaging and shipment of Type B radioactive material.

The packaging consists of an outer double skin insulated keg (Keg 2863), an insulating cork liner, an outer resealable containment vessel (Can 2870), and an inner resealable containment vessel (Can 2871). These resealable vessels are designed to remain within regulatory limits regarding leakage rate, under both normal



C/V = containment vessel.

Figure D–3 SAFKEG 2863B

and accident conditions of transport. The nominal weight of the packaging is 103.5 kilograms (228 pounds), excluding contents. The maximum contents weight is 20 kilograms (44 pounds). The keg and containment vessels along with the nomenclature used in the packaging description and analysis are provided in Figure D–2. The containment boundary for each containment vessel consists of the body, lid, and inner o-ring. The outer o-rings of the containment vessels and test port seals are not part of the containment boundary. The design pressure for the package is 8 bar absolute/116 pounds per square inch absolute (7 bar gauge/101.5 pounds per square inch gauge) which is the bounding pressure for the containment vessels for all environmental conditions.

The Keg 2863 consists of a double skinned stainless steel keg body. A flat stainless steel lid is secured with studs and nuts. The lid may be secured to prevent unauthorized removal by a padlock attached to a lockpin welded to the keg closure flange. Studs are provided for fitting tamper indicating devices in accordance with 10 CFR 71.43(b). The cavity between the double skin is filled with a thermal insulating and shock absorbing phenolic resin foam. This cavity is normally sealed but will vent through the vent plug at the bottom of the keg during a hypothetical accident fire. The assembled SAFKEG 2863B has an overall length of 760 millimeter (30 inches) and an overall diameter of 425 millimeter (16.7 inches). The keg is fitted with a nameplate that complies with the requirements in 10 CFR 71.85 and 49 CFR 173.444.

There is an insulating cork liner between the Keg 2863 and the outer containment vessel Can 2870. The top and bottom of this cork liner varies in thickness from 75 millimeters (3 inches) at the top to 28 millimeters (1.1 inches) at the base of the keg. The side-wall thickness of the cork liner varies from 14.5 millimeters (0.57 inches) at the top to 59.5 millimeters (2.3 inches) at the bottom.

The outer containment vessel (Can 2870) is made from stainless steel. The body is fabricated from four pieces, welded and tested. The seal between the body and the lid is effected by two, 3-millimeter (0.118-inch) chord diameter o-ring face seals; access to the interspace between the two o-rings is provided for operational and maintenance leak testing. The lid is held in position by a threaded retaining ring. Both the retaining ring and the lid are recessed into the body of the container, thus reducing the vulnerability of the closure.

The design, materials, and construction of the inner containment vessel (Can 2871) are similar to those of the outer containment vessel, but the inner containment vessel is smaller to enable it to fit inside the outer. The cavity has an overall length of 401 millimeters (15.75 inches) (to the bottom of the curved base) and a minimum diameter of 127.6 millimeters (5.024 inches). The vessel operates at atmospheric pressure, although the internal pressure may vary due to absorption of oxygen by the contents and heating of the gasses within the containment vessels by decay heat of the contents, by radiolysis of organic materials (when present) and atmospheric temperature and pressure.

D.7.2.2 DT-22 and D-23 Packages

DT-23 and DT-23 packages are functionally similar to the previously described SAFKEG, in that they rely on a steel drum and are supported by packing material to protect the hardened inner container. Each consists of an outer drum and an inner container made of Type 304 stainless steel, with Celotex fiber insulation between the drum and liner. The DT-22 outer structure is a 170-liter (45-gallon) drum about 64 centimeters (25 inches) in diameter and 71 centimeters (28 inches) in height. The inner container is made of 0.4-centimeter (0.16-inch) stainless steel and is about 32centimeters (12 inches) in diameter and 44 centimeters (17 inches) in height. The empty package weighs about 108 kilograms (238 pounds). The DT-23 outer structure is a 413-liter (109-gallon) drum about 84 centimeters (33 inches) in diameter and 104 centimeters (41 inches) in height. The inner container is made of 0.4-centimeter (0.16-inch) stainless steel and is about 53 centimeters (21 inches) in diameter and 69 centimeters (27 inches) in height. Both packages are double-containment packages that can be used to transport weapon parts, highly enriched uranium or plutonium. The empty package weighs about 246 kilograms (542 pounds).

D.7.2.3 Model FL Packages

FL 10-1 consists of two, 16-gauge 208-liter (55-gallon) drums welded end to end, approximately 172 centimeters (68 inches) long and 57 centimeters (22.5 inches) in diameter. The outer drum closure is accomplished by at least a 12-gauge bolt-locking ring with drop-forged lugs, one of which is threaded to receive at least a 1.6 centimeter (5/8-inch) diameter bolt and lock nut. The pressure vessel support mechanism consists of wood supports, steel inner sleeve and nut ring to receive the containment vessel, and fire resistant phenolic foam, formed in place. Gas relief holes are provided in the outer steel drum.

The containment vessel is a 304L stainless steel 12.7-centimeter (5-inch) Schedule 40 pipe, approximately 136 centimeters (53.5 inches) long, with a 304L stainless steel 1.3-centimeter (0.5-inch)-thick welded bottom plate and a 304L stainless steel slip-on flange and blind flange which is fastened by eight, 1.9-centimeter (0.75-inch) steel bolts. The flange closure is gasketed by two fluoroelastomer o-rings with a pressure tap between the two o-ring grooves. During shipment, the o-ring groove pressure tap is sealed with a pipe plug with threads wrapped in teflon tape. A steel valve is screwed into the blind flange of the containment vessel. The valve is sealed by a pipe cap (threads wrapped with Teflon tape) and is protected by a section of Schedule 40 pipe welded to the top of the flange. The packaging has a maximum gross weight of 234 kilograms (515 pounds).

The Model FL package is certified to carry a variety of fissile material solutions and dry compounds. The maximum quantities per package and the number of packages per shipment vary with the amount and form of the contents.

D.7.2.4 U.S. Department of Transportation 6M Packages

The original U.S. Department of Transportation 6M packaging (49 CFR 173.354) was Dow Chemical Corporation’s Model 1518, a 38-liter (10-gallon) container, approved by the U.S. Atomic Energy Commission (now DOE) in March 1967 and issued as U.S. Department of Transportation Special Permit 5000 the following month. The 6M packaging was issued in December 1968 to cover a variety of similar containers ranging in capacity from 38 to 417 liters (10 to 110 gallons). The 6M packaging is currently authorized by U.S. Department of Transportation regulations for shipment of Type B quantities of radioactive materials (49 CFR 173, Subpart I).

In 1980, NRC expressed concern about shipping plutonium in the 6M packaging. Because of changing specifications, secondary containment for plutonium was required (10 CFR 71). NRC decided the 6M packaging was adequate as an overpack.

As secondary containment was required, NRC also wanted assurance that U.S. Department of Transportation Specification 2R (Inside Containment Vessel) would meet the new leak rates specified in the International Atomic Energy Agency regulations (Kelly 1994).

General construction requirements for the 6M packaging may be found in 49 CFR 178.354, *Specification 6M; Metal Packaging*, and for the 2R vessel in 49 CFR 178.360. Refer to **Figure D–4** for an example of a typical 6M package with the 2R inner vessel or container.

In response to U.S. Nuclear Regulatory Commission concerns, the DOE and its contractors expended considerable effort to determine what role the 6M packaging should have for shipping DOE-owned

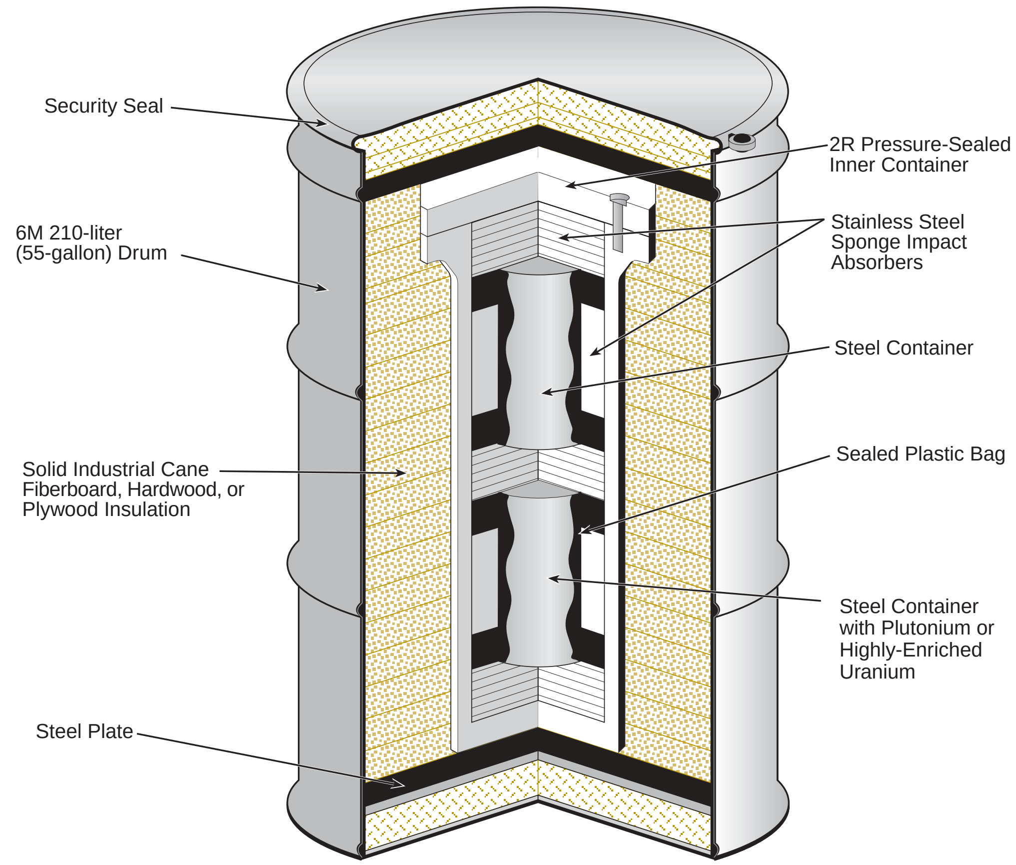


Figure D–4 Typical Assembly of 6M, Type B Packaging for Plutonium

plutonium. Technical reviews and safety assessments have been performed on 6M specification packaging, 2R inner container welds associated with 6M packaging, the types and quantities of radioactive material being shipped in 6M packaging, and future packaging to replace the 6M. In 1988, a DOE task force performed a technical review of the 6M packaging configuration. The review and subsequent documentation found that the 6M packaging configuration merits continued use (SNL 1988).

The task force that studied this subject recognized that the use of the 6M is authorized by current U.S. Department of Transportation regulations and recommended procedural improvements for its continued use. It was determined that the number of product can configurations and the number of 6M drum sizes should be reduced, and that the major shipping sites should coordinate an effort to minimize the number of can configurations and drum sizes used for shipment of plutonium.

In 1988, weld defects were found in the DT-14A packages fabricated by a particular manufacturer. Because the manufacturer was a major supplier of 2R inner containers, the integrity of 2R inner containers became a concern. In 1989, DOE Headquarters issued directives (Wade 1989) to all Defense Programs Operations Offices that future shipments of Type B radioactive material in the 6M packaging implement the applicable requirements as specified in the DOE task force's technical document (SNL 1988). The Container Weld Advisory Committee was formed in 1989 to develop recommendations and provide criteria for specific weld issues related to the 2R inner container. The Container Weld Advisory Committee recommended static force testing to ensure that the weld was strong enough to withstand the postulated hypothetical accident condition loadings. Leak testing was specified to ensure that no leak paths existed in the weld. The safety enhancements developed will allow interim use of the 6M until a replacement container is available. As a result, 2R inner-containment vessels have had their bottom plate welds static force tested and leak tested. The purpose of the added requirements is to allow interim use of the 6M configuration until a replacement container is available (Kelly 1994).

The outer shell of the 6M packaging is made of straight-sided steel, with welded body seams, and in accordance with U.S. Department of Transportation Specification 6C or 17C, with each length to contain 3 wedged or rolled rolling hoops as prescribed for either of these specifications. A removable head has one or more corrugations in the cover near the periphery. For a packaging exceeding 57 liters (15 gallons) volume, the head must be crowned (convex), not extending beyond the level of the chime, with a minimum convexity of 1 centimeter (3/8 inches).

Each drum has at least four 1.2-centimeter (0.5-inch) diameter vents near the top, each covered with a weatherproof tape or fusible plug, or equivalent device. A layer of porous refractory fiber may be placed behind the pressure-relief vent holes.

The closure device has means for the attachment of a tamper-proof lock wire and seal.

The inner containment vessel is fixed within the outer shell by solid centering media, with the sides of the inner vessel protected by at least 9.5 centimeters (3.75 inches) of insulation media, and the ends with at least the thickness as prescribed in 49 CFR 178.104-3(a)(1). The centering media is usually machined discs and rings made of solid industrial can fiberboard having a density of at least 0.24 grams per cubic centimeter (15 pounds per cubic foot) fitted such that the radial clearances between the fiberboard, inner vessel, and shell do not exceed 6 millimeters (.25 inches).

When necessary, shielding may be provided within the 2R containment vessel. Any radiation shielding material used must be placed within the inner containment vessel or must be protected in all directions by at least the thickness of the thermal insulating material.

The primary containment vessel is constructed to U.S. Department of Transportation Specification 2R (49 CFR 178.360). Each vessel is made of stainless steel, malleable iron, or brass, or other material having equivalent physical strength and fire resistance.

The closure device is a screw-type cap or plug. The number of threads per inch must not be less than U.S. standard pipe threads and must have sufficient length of thread to engage at lease five threads when securely tightened. Pipe threads are luted with an appropriate nonhardening compound which must be capable of withstanding up to 149 degrees celsius (300 degrees fahrenheit) without loss of efficiency. Tightening torque is adequate to maintain leak tightness with the specific luting compound.

D.7.3 Representative Routes

Representative truck routes were selected for the shipments from TA-18 to SNL/NM, NTS and ANL-W. The routes were selected consistent with current routing practices and all applicable routing regulations and guidelines. However, the routes were determined for risk assessment purposes. They do not necessarily represent the actual routes that would be used to transport radioactive materials in the future. Specific routes cannot be identified in advance. The representative truck routes are shown in **Figure D–5**.

Route characteristics that are important to the radiological risk assessment include the total shipment distance and the population distribution along the route. The specific route selected determines both the total

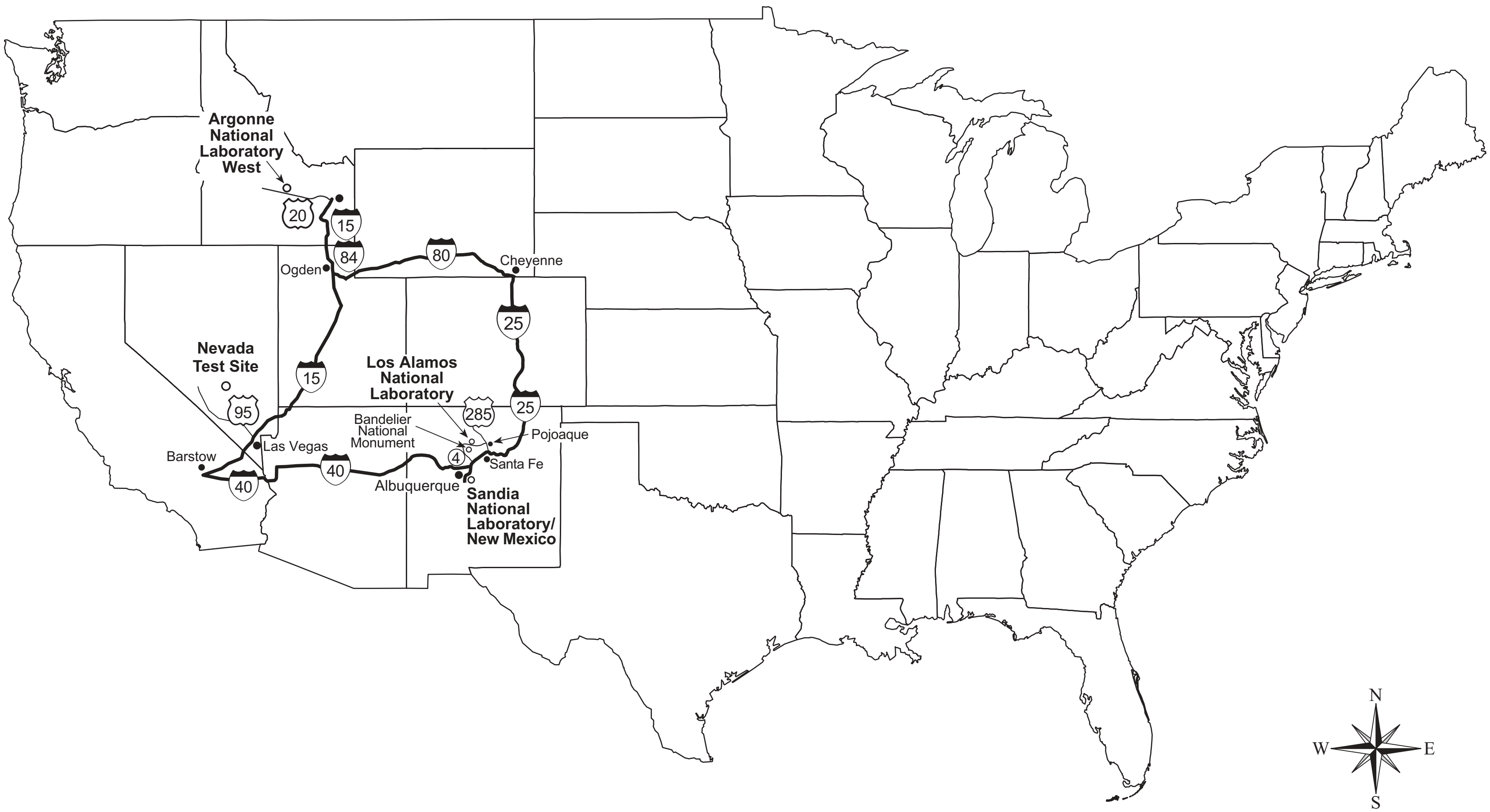


Figure D–5 Representative Overland Truck Route

potentially exposed population and the expected frequency of transportation-related accidents. Route characteristics are summarized in **Table D–1**. The population densities along each route are derived from 1990 U.S. Bureau of Census data. Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 54 persons per square kilometer (0 to 139 persons per square mile); the suburban range is from 55 to 1,284 persons per square kilometer (140 to 3,326 persons per square mile); and the urban range includes all population densities greater than 1,284 persons per square kilometer (3,326 persons per square mile). The affected population, for route characterization and incident-free dose calculation, includes all persons living within 800 meters (0.5 mile) of each side of the road.

Table D–1 Potential Shipping Routes Evaluated for the TA-18 Relocation EIS

From	*To*	*Distance (kilometers)*	*Percentages in Zones*			*Population Density in Zone (per square kilometer)*			*Number of Affected Persons*
			Rural	*Suburban*	*Urban*	*Rural*	*Suburban*	*Urban*	
Truck Routes									
TA-18	NTS	1,671	93.4	5.9	0.7	3.6	381	2,096	108,000
TA-18	SNL/NM	167	78.9	16.1	5	8.6	431	2,125	49,000
TA-18	ANL-W	1,873	89.4	9.1	1.4	4.5	393	2,085	207,000

D.7.4 External Dose Rates

The external dose rates are conservatively estimated using engineering judgment. Based on DOE's operational experience, external dose rates from packages containing enriched uranium, plutonium, and thorium would generally be low. Therefore, for 82 of the 87 shipments of radioactive and SNM, the dose rate at 1 meter (3.3 feet) from the vehicle is estimated to be 1 millirem per hour. It is assumed that 5 of the 87 shipments would be carrying material, such as uranium-233, that has a much higher contact dose rate. For these shipments, a dose rate of 10 millirem per hour, at 1 meter (3.3 feet) from the vehicle, was assumed. This is just below the regulatory limit of 10 millirem per hour at 2 meters (6.6 feet). Additionally, about 5 shipments are assumed to be needed to ship the machines and 10 metric tons (11 tons) of depleted and natural uranium and thorium (which do not require special security measures such as described in Section D.5). The average dose rate for the depleted and natural uranium and thorium shipments is estimated to be 0.1 millirem at 1 meter (3.3 feet) from the vehicle.

D.7.5 Health Risk Conversion Factors

The health risk conversion factors used to estimate expected cancer fatalities were: 0.0005 and 0.0004 latent cancer fatalities per person-rem for members of the public and workers, respectively (NCRP 1993).

D.7.6 Accident Frequencies

For the calculation of accident risks, vehicle accident and fatality rates are taken from data provided in ANL/ESD/TM-150 (Saricks and Tompkins 1999). Accident rates are generically defined as the number of accident involvements (or fatalities) in a given year per unit of travel in that same year. Therefore, the rate is a fractional value, with accident-involvement count as the numerator of the fraction and vehicular activity (total travel distance in truck-kilometers) as its denominator. Accident rates are generally determined for a multiyear period. For assessment purposes, the total number of expected accidents or fatalities is calculated by multiplying the total shipment distance for a specific case by the appropriate accident or fatality rate.

For truck transportation, the rates presented are specifically for heavy combination trucks involved in interstate commerce (Saricks and Tompkins 1999). Heavy combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other. Heavy combination trucks are typically used for radioactive material shipments. The truck accident rates are computed for each state based on statistics compiled by the Federal Highway Administration, Office of Motor Carriers from 1994 to 1996. A fatality caused by an accident is the death of a member of the public who is killed instantly or dies within 30 days due to the injuries sustained in the accident.

The HIGHWAY code classifies highways as rural, suburban or urban, and provides the distance and population information for use in RADTRAN. These codes require accident frequency data calculated for rural, urban and suburban zones. An older report, ANL/ESD/TM-68 (Saricks and Kvitek 1994), reports accident rates for Federally Aided Interstates in urban and rural areas, and a composite accident rate for all Federally Aided Interstates. TM-150 does not provide data that can be directly used to estimate frequencies for rural, urban and suburban zones. The ratios of accident frequencies for the zones was calculated from TM-68 data, and used with the newer TM-150 data to establish up-to-date accident frequency estimates. Since the distance traveled on non-interstate highways was very small compared to the distance traveled on interstates, and the accident rates are similar, interstate accident rates were used for all roads. TM-68 and TM-150 information is used for both the accident rate estimate for the radiological risk, and the fatal accident rate estimate for the nonradiological risk.

For SST/SGT transportation, the rates presented are specifically adjusted for the experience of the DOE Transportation Safeguards Division. Between fiscal year 1984 and fiscal year 1998, the Transportation Safeguards Division reports 0.058 accidents per million kilometers (0.096 accidents per million miles) (Claus and Shyr 1999). Using influence factors from SAND93-0111 (Phillips, Clauss, and Blower 1994), accident frequencies for rural, urban, and suburban driving can be estimated.

D.7.7 Container Accident Response Characteristics and Release Fractions

D.7.7.1 Development of Conditional Probabilities

NUREG-0170 (NRC 1977) originally was used to estimate the conditional probabilities associated with the accidents involving transportation of radioactive materials. The analysis was primarily performed using best engineering judgments and presumptions concerning cask response. Design parameters of the representative casks were chosen to meet the minimum test criteria specified in 10 CFR 71. The study is believed to provide realistic, yet conservative, results for radiological releases under transport accident conditions.

As discussed above, the accident consequence assessment only considers the potential impacts from the most severe transportation accidents. In terms of risk, the severity of an accident must be viewed in terms of potential radiological consequences, which are directly proportional to the fraction of the radioactive material within a cask that is released to the environment during the accident. Although regions span the entire range of mechanical and thermal accident loads, they are grouped into accident categories that can be characterized by a single set of release fractions and are, therefore, considered together in the accident consequence assessment. The accident category severity fraction is the sum of all conditional probabilities in that accident category.

D.7.7.2 Release Fraction Assumptions

The release fractions for each material form (metal, non-metallic solid, liquid, powder and gaseous) were taken from NUREG-0170 (NRC 1977) and the aerosol and respirable fractions were taken from the

RADTRAN 5 User Guide (Neuhauser and Kanipe 2000). These accident analysis parameters are generally applicable to a variety of materials and are conservative.

D.7.8 Nonradiological Risk (Vehicle-Related)

Vehicle-related health risks resulting from incident-free transport may be associated with the generation of air pollutants by transport vehicles during shipment and are independent of the radioactive nature of the shipment. The health end-point assessed under incident-free transport conditions is the excess latent mortality due to inhalation of vehicle exhaust emissions. The risk factor for pollutant inhalation in terms of latent mortality is 1×10^{-7} mortality per kilometer (1.6×10^{-7} per mile) of truck travel in urban areas (Neuhauser and Kanipe 2000). The risk factors are based on regression analyses of the effects of sulfur dioxide and particulate releases from diesel exhaust on mortality rates. Excess latent mortalities are assumed to be equivalent to latent cancer fatalities. Vehicle-related risks from incident-free transportation (affecting the population in urban areas along the transportation route) are calculated for each case by multiplying the total distance traveled in urban areas by the appropriate risk factor. Similar data are not available for rural and suburban areas.

Risks are summed over the entire route and over all shipments for each case. This method has been used in several EISs to calculate risks from incident-free transport. Lack of information for rural and suburban areas is an obvious data gap, although the risk factor would presumably be lower than for urban areas because of lower total emissions from all sources and lower population densities in rural and suburban areas.

D.7.9 Packaging and Handling Doses

TA-18 materials would be placed into packages for onsite or offsite shipment. These packages would be loaded onto SST/SGT or commercial trailers, shipped to the receiving site at LANL, NTS, SNL/NM, or ANL-W, unpacked and placed into storage. DOE's estimate of the radiation doses likely to be received by personnel moving (which includes handling, packaging, loading, and unloading) radioactive materials from TA-18 as part of moving the materials to another location is based on a review of TA-18 operational doses. The major assumption for this analysis is that the dose received from removing TA-18 material from its storage location, setting up experiments, and returning the material to storage is essentially the same as the dose for moving the radioactive materials. Another assumption is that the dose rate for the material handled for experiments is representative of the dose rates of all the TA-18 material being moved.

Based on a review of the radiological exposure information, in about 250 working days of the year 2000, material handlers working at TA-18 received about 0.250 person-rem (LANL 2001). For the purposes of the analysis, it was estimated that the workers handled the equivalent of one package per day. Therefore, TA-18 personnel received about 0.001 person-rem (or 1 person-millirem) for each package handled.

To estimate the potential handling dose to site workers at both the origin and the destination, this EIS assumed an average of 1 person-millirem per package would be handled. The number of packages to be placed in one shipment (a full SST/SGT or a commercial trailer) would be less than 25 per shipment. For the purpose of bounding the impacts, 25 packages in each of the 92 shipments was assumed. Multiplying these numbers equals 2,300 packages, which can be multiplied by the estimated dose to calculate 2.3 person-rem for the entire operation. Using the same approach, and assuming 20 packages would be required to move the material for SHEBA, estimates 0.02 person-rem for moving SHEBA material. Under the TA-18 Upgrade Alternative, there would be some movement of material to support modifications. The dose would be smaller than the dose received during normal operations and is estimated to be, at most, 0.250 person-rem, i.e., a dose equal to that associated with a year of material handling at TA-18.

D.8 RISK ANALYSIS RESULTS

Per-shipment risk factors have been calculated for the collective populations of exposed persons and for the crew for all anticipated routes and shipment configurations. The radiological risks are presented in doses per shipment for each unique route, material, and container combination. The radiological dose per shipment factors for incident-free transportation are presented in **Table D–2** for the transportation routes analyzed for this EIS.

Doses are calculated for the crew, off-link public (i.e., people living along the route), on-link public (i.e., pedestrians and drivers along the route), and public at rest and fueling stops (i.e., stopped cars, buses and trucks, workers, and other bystanders). For the onsite shipments (LANL Alternatives) quantitative impact analysis is not necessary. Since the shipments would be over a short distance, on closed DOE-controlled roads, LANL procedures ensure public safety. No incident free analysis is necessary because the public is not close enough to the vehicles to received measurable exposure. Worker dose is included in the process and handling dose estimates because the same personnel would be moving the radioactive and special nuclear material. No accident analysis is necessary because potential accidents during movement are bounded in frequency and consequence by handling accidents. Once the package is closed for the low-speed movement to the nearby building, the likelihood and consequence of any foreseeable accident are very small and not further quantified.

The radiological dose risk factors for transportation accidents are also presented in Table D–2. The accident risk factors are called "dose risk" because the values incorporate the spectrum of accident severity probabilities and associated consequences. The accident dose is very low because, although persons are residing in an 80 kilometers (50 miles) radius of the road, they are generally quite far from the road. Since RADTRAN 5 uses an assumption of homogeneous population from the road out to 80 kilometers (50 miles), it would greatly overestimate the actual doses. The accident analysis was performed using average equivalent plutonium-239 loading per shipment for both high- and low-contact dose materials.

The nonradiological risk factors are presented in fatalities per shipment in **Table D–3**. Separate risk factors are provided for fatalities resulting from exhaust emissions (caused by hydrocarbon emissions known to be carcinogens) and transportation accidents (fatalities resulting from impact).

Table D–4 shows the risks of transportation for each alternative. The risks are calculated by multiplying the previously given per-shipment factors by the number of shipments over the duration of the program and, for the radiological doses, by the health risk conversion factors.

The risks to various exposed individuals under incident-free transportation conditions have been estimated for hypothetical exposure scenarios. The estimated doses to workers and the public are presented in **Table D–5.**

All doses are presented on a per-event basis (person-rem per event) because it is not likely that the same person will be exposed to multiple events. The maximum dose to a crew member is based on the same individual being responsible for driving every shipment for the duration of the campaign. Note that the potential exists for larger individual exposures if multiple exposure events occur. For example, the dose to a person stuck in traffic next to a shipment for 10 minutes is calculated to be 0.03 millirem. However, since the intersite shipments pass through urban areas, a 30-minute exposure time is considered. Using the estimated dose rates, the maximally exposed individual would receive 0.1 millirem.

Table D–2 Radiological Risk Factors for Single Shipments

From TA-18 To	Material	Incident-Free Dose (person-rem)					Accident Dose (person-rem)
			Public				
		Crew	Off-Link	On-Link	Stops	Total	
NTS	Low-contact dose	0.00042	0.000032	0.00035	0.00018	0.00056	3.3×10^{-7}
	High-contact dose	0.042	0.0032	0.035	0.018	0.056	
	Uranium and thorium	0.000042	3.2×10^{-6}	0.000035	0.000064	0.00010	$<1.0 \times 10^{-10}$
SNL/NM	Low-contact dose	0.000042	9.5×10^{-6}	0.000041	0.000018	0.000068	8.2×10^{-8}
	High-contact dose	0.0042	0.0010	0.0041	0.0018	0.0068	
	Uranium and thorium	4.2×10^{-6}	9.5×10^{-7}	4.1×10^{-6}	6.5×10^{-6}	0.000012	$<1.0 \times 10^{-10}$
ANL-W	Low-contact dose	0.00047	0.000055	0.00041	0.00020	0.00066	4.3×10^{-7}
	High-contact dose	0.047	0.0055	0.041	0.020	0.066	
	Uranium and thorium	0.000047	5.5×10^{-6}	0.000041	0.00012	0.00012	$<1.0 \times 10^{-10}$

Table D–3 Nonradiological Risk Factors per Shipment

Nonradiological Risk Estimates (fatalities/shipment)				
	Exhaust Emission		Accident	
From TA-18 To	Truck	SST	Truck	SST
NTS	2.3×10^{-6}	3.0×10^{-6}	3.0×10^{-5}	5.7×10^{-7}
SNL/NM	1.7×10^{-6}	2.2×10^{-6}	3.0×10^{-6}	8.8×10^{-8}
ANL-W	5.2×10^{-6}	6.8×10^{-6}	3.4×10^{-5}	7.2×10^{-7}

Table D–4 Risks of Transporting the Hazardous Materials[a]

			Incident-Free				*Accident*	
			Radiological			*Nonradiological*		
Alternative	*Number of Shipments*	*Distance on Public Roads (kilometers)*	*Vehicle Crew*	*Packaging and Handling*	*Public*	*Emission*	*Traffic*	*Radiological*
No Action	(b)							
TA-18 Upgrade	(b)			0.0001				
LANL New Facility	(c)	less than 1,000		0.0009				
NTS	92	307,000	0.00010	0.0009	0.00016	0.00028	0.00020	1.4×10^{-8}
SNL/NM	92	31,000	0.000010	0.0009	0.00020	0.00020	0.000023	3.5×10^{-9}
ANL-W	92	345,000	0.00011	0.0009	0.00019	0.00062	0.00023	1.9×10^{-8}

[a] All risks are expressed as number of latent cancer fatalities, except for the Accident-Traffic column, which lists number of accident fatalities.
[b] Very little onsite and no offsite transportation for the No Action and TA-18 Upgrade Alternatives, therefore no accident or public risk analysis was performed.
[c] Probably more shipments than other alternatives, but not evaluated because population, distance, and accident risk would be smaller than other alternatives. The shipments would be on site at LANL, therefore, no accident or public risk analysis was performed.

Table D–5 Estimated Dose to Exposed Individuals During Incident-Free Transportation Conditions

Receptor		*Dose to Maximally Exposed Individual*
Workers	Crew member (truck driver) [a]	0.137 rem per year
	Inspector	0.000029 rem per event [b]
Public	Resident	4.0×10^{-9} rem per shipment
	Person in traffic congestion	0.00011 rem per event [b]

[a] Assumes that an individual driver takes every shipment.
[b] Event for an inspector means during inspection period, and for a person in traffic means during a 30-minute traffic jam.

The cumulative dose to a resident was calculated assuming all shipments passed his or her home. The cumulative doses assume that the resident is present for every shipment and is unshielded at a distance of 30 meters (about 98 feet) from the route. Therefore, the cumulative dose depends on the number of shipments passing a particular point and is independent of the actual route being considered. The maximum dose to this resident, if all the material were to be shipped via this route, would be less than 0.01 millirem.

The estimated dose to transportation crew members is presented for a commercial crew. No credit is taken for the shielding associated with the tractor or trailer.

The previously described accident risk assessment and the impacts provided in Table D–4 take into account the entire spectrum of potential accidents, from the fender-bender to extremely severe. To provide additional insight into the severity of accidents in terms of the potential dose to a maximally exposed individual, an accident consequence assessment has been performed for a hypothetical accident scenario. This accident would fall into Severity Category 8 of the NUREG-0170 accident matrix (NRC 1977), which is the only category with a release of radioactive material. To incur this level of damage, the vehicle would have to collide with an immovable object at a speed much greater than 88 kilometers per hour (55 miles per hour), and the contents of the vehicle would have to end up in a sustained fire. This analysis was performed irrespective of its potential likelihood. The maximally exposed individual was assumed to be 33 meters (108 feet) directly downwind of the accident and to remain at that location for 40 minutes. The accident could result in a dose of 139 rem to the maximally exposed individual.

D.9 LONG-TERM IMPACTS OF TRANSPORTATION

The Programmatic Spent Nuclear Fuel EIS (DOE 1995) analyzed the cumulative impacts of all transportation of radioactive materials, including impacts from reasonably foreseeable actions that include transportation of radioactive material for a specific purpose and general radioactive materials transportation that is not related to a particular action. The total worker and general population collective doses are summarized in **Table D–6**. The table shows that the impacts of this program are quite small compared with overall transportation impacts. Total collective worker dose from all types of shipments (historical, the alternatives, reasonably foreseeable actions, and general transportation) was estimated to be 320,000 person-rem (130 latent cancer fatalities) for the period 1943 through 2035 (93 years). Total general population collective dose was also estimated to be 320,000 person-rem (160 latent cancer fatalities). The majority of the collective dose for workers and the general population was due to the general transportation of radioactive material. Examples of these activities are shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities. The total number of latent cancer fatalities estimated to result from radioactive materials transportation over the period between 1943 and 2035 was 290. Over this same period (93 years), approximately 28 million people would die from cancer, based on 300,000 cancer fatalities per year. It should be noted that the estimated number of transportation-related latent cancer fatalities would be indistinguishable from other latent cancer fatalities, and the transportation-related latent cancer fatalities are 0.0010 percent of the total number of latent cancer fatalities.

D.10 UNCERTAINTY AND CONSERVATISM IN ESTIMATED IMPACTS

The sequence of analyses performed to generate the estimates of radiological risk for transportation includes: (1) determination of the inventory and characteristics, (2) estimation of shipment requirements, (3) determination of route characteristics, (4) calculation of radiation doses to exposed individuals (including estimating of environmental transport and uptake of radionuclides), and (5) estimation of health effects. Uncertainties are associated with each of these steps. Uncertainties exist in the way that the physical systems being analyzed are represented by the computational models; in the data required to exercise the models (due to measurement errors, sampling errors, natural variability, or unknowns simply caused by the future nature of the actions being analyzed); and in the calculations themselves (e.g., approximate algorithms used by the computers).

Table D–6 Cumulative Transportation-Related Radiological Collective Doses and Latent Cancer Fatalities (1943 to 2035)

Category	*Collective Worker Dose (person-rem)*	*Collective General Population Dose (person-rem)*
TA-18 relocation transportation impacts (from Table D–5)	less than 1	less than 1
Other Nuclear Material Shipments		
Truck	11,000	50,000
Rail	820	1,700
General transportation (1943–2035)	310,000	270,000
Total collective dose	322,000	322,000
Total latent cancer fatalities	130	160

Source: DOE 1995.

In principle, one can estimate the uncertainty associated with each input or computational source and predict the resultant uncertainty in each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final, or absolute, result; however, conducting such a full-scale quantitative uncertainty analysis is often impractical and sometimes impossible, especially for actions to be initiated at an unspecified time in the future. Instead, the risk analysis is designed to ensure, through uniform and judicious selection of scenarios, models, and input parameters, that relative comparisons of risk among the various alternatives are meaningful. In the transportation risk assessment, this design is accomplished by uniformly applying common input parameters and assumptions to each alternative. Therefore, although considerable uncertainty is inherent in the absolute magnitude of the transportation risk for each alternative, much less uncertainty is associated with the relative differences among the alternatives in a given measure of risk.

In the following sections, areas of uncertainty are discussed for the assessment steps enumerated above. Special emphasis is placed on identifying whether the uncertainties affect relative or absolute measures of risk. The reality and conservatism of the assumptions are addressed. Where practical, the parameters that most significantly affect the risk assessment results are identified.

D.10.1 Uncertainties in Material Inventory and Characterization

The inventories and the physical and radiological characteristics are important input parameters to the transportation risk assessment. The potential amount of transportation for any alternative is determined primarily by the projected dimensions of package contents, the strength of the radiation field, the heat that must be dissipated, and assumptions concerning shipment capacities. The physical and radiological characteristics are important in determining the material released during accidents and the subsequent doses to exposed individuals through multiple environmental exposure pathways.

Uncertainties in the inventory and characterization are reflected in the transportation risk results. If the inventory is overestimated (or underestimated), the resulting transportation risk estimates are also overestimated (or underestimated) by roughly the same factor. However, the same inventory estimates are used to analyze the transportation impacts of each of the EIS alternatives. Therefore, for comparative purposes, the observed differences in transportation risks among the alternatives, as given in Table D–4, are believed to represent unbiased, reasonably accurate estimates from current information in terms of relative risk comparisons.

D.10.2 Uncertainties in Containers, Shipment Capacities, and Number of Shipments

The transportation required for each alternative is based in part on assumptions concerning the packaging characteristics and shipment capacities for commercial trucks. Representative shipment capacities have been defined for assessment purposes based on probable future shipment capacities. In reality, the actual shipment capacities may differ from the predicted capacities such that the projected number of shipments and, consequently, the total transportation risk would change. However, although the predicted transportation risks would increase or decrease accordingly, the relative differences in risks among alternatives would remain about the same.

D.10.3 Uncertainties in Route Determination

Representative routes have been determined between all origin and destination sites considered in the EIS. The routes have been determined to be consistent with current guidelines, regulations, and practices, but may not be the actual routes that would be used in the future. In reality, the actual routes could differ from the representative ones with regard to distances and total population along the routes. Moreover, since materials could be transported over an extended time starting at some time in the future, the highway infrastructures and the demographics along routes could change. These effects have not been accounted for in the transportation assessment; however, it is not anticipated that these changes would significantly affect relative comparisons of risk among the alternatives considered in the EIS. Specific routes cannot be identified in advance because the routes are classified to protect national security interests.

D.10.4 Uncertainties in the Calculation of Radiation Doses

The models used to calculate radiation doses from transportation activities introduce a further uncertainty in the risk assessment process. Estimating the accuracy or absolute uncertainty of the risk assessment results is generally difficult. The accuracy of the calculated results is closely related to the limitations of the computational models and to the uncertainties in each of the input parameters that the model requires. The single greatest limitation facing users of RADTRAN, or any computer code of this type, is the scarcity of data for certain input parameters.

Uncertainties associated with the computational models are reduced by using state-of-the-art computer codes that have undergone extensive review. Because many uncertainties are recognized but difficult to quantify, assumptions are made at each step of the risk assessment process intended to produce conservative results (i.e., overestimate the calculated dose and radiological risk). Because parameters and assumptions are applied consistently to all alternatives, this model bias is not expected to affect the meaningfulness of relative comparisons of risk; however, the results may not represent risks in an absolute sense.

Post accident mitigative actions are not considered for dispersal accidents. For severe accidents involving the release and dispersal of radioactive materials in the environment, no post accident mitigative actions, such as interdiction of crops or evacuation of the accident vicinity, have been considered in this risk assessment. In reality, mitigative actions would take place following an accident according to U.S. Environmental Protection Agency radiation protection guides for nuclear incidents (EPA 1992). The effects of mitigative actions on population accident doses are highly dependent upon the severity, location, and timing of the accident. For this risk assessment, ingestion doses are only calculated for accidents occurring in rural areas (the calculated ingestion doses, however, assume all food grown on contaminated ground is consumed and is not limited to the rural population). Examination of the severe accident consequence assessment results has shown that ingestion of contaminated foodstuffs contributes about 50 percent of the total population dose for rural accidents. Interdiction of foodstuffs would act to reduce, but not eliminate, this contribution.

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